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Analysis OF Energy Efficiency Practices of SMEs in Ghana: An application of Product Generational Dematerialisation

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Abstract

Reducing the amount of energy used in producing a given output is a cost-effective way of tackling global warming. In addition, energy efficiency promotes energy security and saves cost. This study is structured in three parts. First, the energy efficiency practices of small and medium scale enterprises in rural Ghana are investigated. Second, the study applies the Product Generational Dematerialisation method to examine the energy efficiency consumption of electricity and fossil fuels in Ghana. Finally, the general unrestricted model (GUM) is applied to energy consumption in Ghana. The results reveal that reduction in energy consumption among SMEs can be attributed mostly to blackouts and not efficiency as indicated by 72% of the respondents. Further, all three models confirmed that the consumption of energy has not been efficient. Further, productivity was found to be a major driver of energy efficiency. The study recommends public education and the use of new appliances ('not second hand') to save energy.

Keywords:

Energy Efficiency, Energy Consumption, Ghana, Product Generational Dematerialization, SMEs

1. Introduction

Small and medium-sized enterprises (SMEs) in developing countries face the hydra-headed challenges of energy access, power outages, access to finance and access to market. These challenges adversely affect productivity, hinder their competitiveness and stifle growth. Thus, for SMEs to maintain their competitiveness, they need to be energy efficient, insofar as energy efficiency reduces the costs of production through reduced energy bills (Worrell et al., 2003). At the national level, energy efficiency is the cheapest way of reducing energy-related carbon emissions. At the firm level, energy efficiency can be a key means of enhancing productivity growth (Jorgenson, 1984; Thollander et al., 2007). Furthermore, environmental policies that seek to curb carbon emissions have positive health effects due to improved air quality. In this regard, the Johannesburg Plan of Implementation (United Nations Department of Economic and Social Affairs – UNDESA, 2002) called on all countries to develop policies and measures contributing towards the reduction of carbon emissions. Energy efficiency can lead to improvements in energy security and ensure a firm's profitability and competitiveness (Gboney, 2009).

A major drawback is that most studies in this field are either carried out in developed economies or at the aggregate level. Furthermore, energy efficiency gains are constrained by the market mechanism and rely upon the extent to which the energy market can be restructured (Jaffe and Stavins, 1994). Indeed, imperfect competition, asymmetric information and incomplete markets, among other inhibitors, can hinder the viability of energy price changes as a major efficiency tool. More generally, economic, behavioural and organizational barriers to energy efficiency gains have been identified (Sorrell, 2007). For instance, Sutherland (1991) studied the market economic barriers to energy efficiency and identified the external cost to energy consumption as one of the reasons governments should initiate in energy efficiency measures. Indeed, Shirley (2005) summarised the barriers into firm profitability, consumer concerns about prices and the preparedness of regulators to restructure energy markets. These different findings calls for SME-specific initiatives, behavioural changes and policy intervention especially in the context a developing country like Ghana.

In 2011, Ghana grew at an astonishing rate of 14.4% – one of the highest rates of growth in the world – and it attained middle-income status (Aiyar et al., 2013). To sustain such growth, various measures have been undertaken by policy makers, businesses and researchers. First, the government recently established a fund (Youth Enterprise Support Fund) to help the country's youth start businesses. Second, researchers and policy makers are calling on the government to remove energy price subsidies. The removal of such subsidies will increase energy prices. The cheapest way of offsetting the impact of energy prices on a firm's performance is through energy efficiency (Patterson, 1996). To this end, the Energy Commission of Ghana encourages energy-efficient practices through education and other measures, such as 'swapping old freezers for new ones' and the replacement of 40 W fluorescent lamps with energy-efficient 36 W fluorescent lamps. Although these policies have been well received, they mostly target household energy consumption. Even at the household level, to the best of our knowledge, no study has yet attempted to evaluate the effects of such energy efficiency policies on energy consumption and productivity in both rural and urban areas. Gboney (2009) is perhaps an exception. He finds that energy efficiency activities undertaken by the Energy Foundation in Ghana within the residential and business sectors have yielded significant monetary savings for consumers. However, Gboney's (2009) study makes a critical untested assumption that the impact of energy efficiency practices in Accra can be generalized and extended to other regions in Ghana, thus neglecting the potentially important effect of geographical location.

According to Shipley and Elliot (2001), SMEs (i) often face difficulties in obtaining the necessary information on new and already existing energy technologies and (ii) lack the capital and technical expertise to invest in energy-efficient technologies. These difficulties are amplified by the relatively low level of attention directed at non-energy-intensive SMEs in policy (Ramirez et al., 2005). Although an increase in energy prices is necessary for energy efficiency, Bertoldi et al. (2005) suggest that this is not always an effective mechanism. Energy-efficient technologies have many advantages, including lower maintenance costs, increased productivity and safer working conditions. Despite these advantages, there is dearth of energy efficiency studies focusing on Ghana. The few attempts that have been made (Van Buskirk et al., 2007; Gboney, 2009; Apeaning and Thollander, 2013) are either sector-specific or focused only on electricity consumption.

This study uses the product generational dematerialization (PGD) indicator to investigate energy efficiency practices in Ghana. The PGD has been applied to dematerialization or decoupling (Recalde et al., 2014), resource use such as that of water (Fiksel et al, 2012) and waste reduction, for example of food waste (Guidat et al., 2015; Van Ewijk and Stegemann, 2014). The PGD indicator measures a change in population in relation to changes in the energy used by this specific population (Ziolkowska and Ziolkowski, 2010). The PGD therefore measures a decrease or an increase in energy consumption by a given population. When energy consumer decreases, it is assumed that the population exhibit energy-saving behaviour which implies efficiency. When energy consumption increases, it is assumed that the population exhibit energy-using behaviour. Materialization' refers to a higher level of energy consumption compared to the reference year, while 'dematerialization' depicts a lower energy consumption compared to the reference year. This study extends recent boundaries in the application of the PGD indicator by considering the efficiency of current electricity, fossil fuel and total energy consumption by comparing changes in energy consumption and changes in population. In this respect, the PGD indicator has three main advantages. First, it allows a dynamic analysis of energy consumption. Second, it helps create a new interpretation and visualization method. Finally, it provides a model that is easily comprehended by the public, policymakers and investors. The study further applies the subjective evaluation method to examine the energy efficiency practices of SMEs and the barriers to energy efficiency in rural Ghana.

2. Literature Review

This section provides an overview of the regulatory framework of energy efficiency in Ghana and an analysis of empirical studies on energy efficiency, productivity and SMEs. It ends with a summary and identification of gaps in the literature.

2.1 Energy efficiency

According to neoclassical economic theory, the production function represents the relationship between the maximum amount of output that can be obtained from a given amount of energy and other inputs (Sorrell, 2007). Energy productivity is essential to the environment and economic growth. First, it is the cheapest way to reduce global emissions of greenhouse gases (McKinsey, 2010). According to the International Energy Agency (IEA, 2006), an additional dollar spent on more efficient electrical equipment, appliances or building systems avoids more than two dollars in investment in electricity. Second, energy saved through productivity measures can also be used in other sectors of the economy. Energy efficiency has been found to be one of the main ways of reducing the impact of the trade-off between a reduction in energy consumption and economic growth. For instance, Dan (2002) finds that there has been a gradual decline in energy consumption in China since 1978 despite increasing growth and attributed this to energy efficiency.

After the oil price shocks of 1973/74 and 1979/80, average productivity in energy use has increased due partly to the replacement of energy-inefficient capital with efficient means (Berndt, 1990). This efficiency can be embodied in the capital or can be disembodied in the form of experience. Berndt (1990) asserts that as one operates a production process, experience is accumulated through learning, which leads to a decreasing unit cost that is independent of the capital stock. He indicates further that an increase in energy productivity usually follows energy price shocks with a considerable time lag. This means major changes in energy use can occur through learning, as when capital stock is replaced with more energy-efficient means. The lifestyle of the consumer can also affect their consumption of energy. Hager & Morawicki (2013) revealed that the practice of putting a lid on a pot during cooking can reduce energy use by 8-fold than cooking without the lid on the pot. Also people who cook in pots that are full to capacity tends to use lesser energy. This is because the efficiency of the pot is reduced by 80% if it is filled a fifth of the way. Cooking food in large batches take advantage of the fact that boiling efficiency increases with pan size and volume of fluid.

2.2 Product generational dematerialization (PGD)

Although there are several sustainable energy consumption indicators, such as the eco-index, the environmental sustainability index and the composite sustainable development index, it has been suggested that they are not sufficient to measure dynamic energy efficiency (Labuschagne et al., 2005). According to the IEA (2006), these indicators measure static efficiency. The PGD on the other hand evaluates simultaneous changes in population and energy consumption (Ziolkowski and Ziolkowska, 2015). The PGD indicator measures a change in population in relation to changes in the energy used by this specific population (Ziolkowska and Ziolkowski, 2010). The indicator can either be used independently or as a complementary instrument in an energy efficiency study. The PGD indicator reveals two main outcomes: either materialization or dematerialization of energy resource use. According to Sun (2001) dematerialization/materialization is 'the real change of energy use in an observation year if that is less/more than the trend based on the levels of a given base year, and if this process occurred throughout the whole observation period'. 'Materialization' refers to a higher level of energy consumption compared to the reference year, while 'dematerialization' depicts a lower energy consumption compared to the reference year. Therefore, materialization occurs when households and industries consume more energy through frequency of use, or excessive use in relation to population growth (Singh et al., 2009). This notwithstanding, energy consumption can be influenced by regulations, lifestyle and environmental concerns. These factors are termed 'taste' factors and are captured by the underlying energy demand trend (see figure 7) (Hunt et al, 2003).

2.3 Regulatory framework for energy efficiency in Ghana

According to Gboney (2009), if appropriate energy efficiency policies are initiated and well implemented, it can help countries to meet increased demand for energy at the lowest cost and also minimize the environmental consequences of energy consumption. Based on this assumption, policy makers in the energy sector have a number of strategies and tactics to encourage energy efficiency and demand-side management. In 1997, the Ghana Energy Commission (EC) was established by an Act of Parliament (Act 541). The purpose of the EC is, amongst other things, to promote the development of renewable energy resources and enhance energy efficiency. In the same year, the Ghana Energy Foundation, a public–private organization, was created with the mandate to develop energy efficiency mechanisms and promote energy efficiency among consumers. Gboney (2009) points out that although the Ghana Energy Foundation has made some progress, most of its activities have been limited to the residential sector.

Electrical appliances imported, produced or used in the country should have energy efficiency labels (see Figure 1). This measure is supported by the Legislative Instrument 2005 (LI 1815).

Ghana Air Conditioner Label

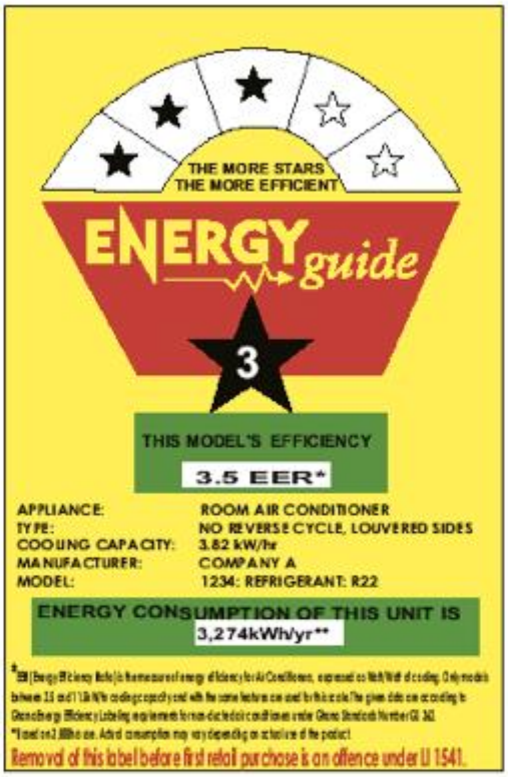

Figure 1. Sample label of energy efficiency for electrical appliances in Ghana

Source: Energy Commission (2014)

2.4 Demand-side management of energy

In 1999, the Ghana Energy Foundation conducted a study on the energy efficiency practices of the Ghana Textile Manufacturing Company and found that the company saved 207,000 KWh in electrical efficiency, translating into 3,519 Ghanaian Cedis (GH₵1.6 = US$1).

Demand-side management (DSM) includes all activities that are performed on the consumption side of an energy system, ranging from exchanging old incandescent light bulbs with compact fluorescent lights (CFLs) up to installing a sophisticated dynamic load management system. Whilst many studies suggest that DSM was ‘utility-driven’ in the past, it might move somewhat towards a ‘customer-driven’ activity in the near future (Palensky and Dietrich, 2011). These authors performed a sequential Monte Carlo simulation to assess the impact of stochastic grid component outages and how far DSM can help in such cases. They identified the correlation and sensitivity of the component capacity variation to the expected shortage of available transmission capacity, as well as the contribution of DSM to transmission capacity. Such centralized structures are sometimes complemented (if not replaced) by flat and freely organized market-driven mechanisms (Mohsenian-Rad et al., 2010). Depending on the timing and the impact of the measures applied on the customer process, DSM can be categorized into a) Energy efficiency (EE), b) Time of use (TOU), c) Demand response (DR) and d) Spinning reserve (SR).

According to Zhou et al. (2008), DSM helps to reduce electrically related accidents, promotes customer satisfaction and reduces operational costs. With the continuous growth rate in electricity demand in Ghana, it can be deduced that utilities have a lot of work to do in terms of increasing investment and the supply side. Despite this, the government is strongly looking at DSM as a means of checking consumption trends and reducing power consumption. Within a few years, consumer households will be equipped with smart metering and knowledgeable appliances. This would be a start for consumers in enabling better monitoring of their electricity consumption and control of loads in private households (Gottwalt et al., 2011).

There are various concerns about DSM, which are not new. The concept surfaced in a study in the 1908s when the need for solutions to influence consumers' use of electricity was raised. DSM was considered even earlier, irrespective of the different kinds of utilities or geographical regions of a country. From a broader perspective, the main DSM techniques which have been implemented are as follows: (i) the use of night time storage heaters and electrical heating (Strabac, 2008); (ii) the adoption of low limiters (activated when demand is above a specific threshold); (iii) reduction in the price base for electricity usage, desirable time slots and curve flattening through the activation of DSM programming (Dincer, 2002); (iv) the inclusion of smart appliances which manage their own operation; (v) smart metering and feedback updates; (vi) the use of frequency regulation to manage generators and loads (Mohsenian-Rad et al., 2010).

One factor which constrains and limits the application of DSM approaches is the existence of stand-alone micro grids. For instance, the demand curve, which shows the match between demand and solar generation over periods of time, must be flattened. The opposite of this strategy must be applied to the normal grid. During wind generation, the localized and stochastic nature of wind demands the application of control strategies and accurate load management to allow for the management of fluctuations and intermittence which can create system failures. Another strategy which can be implemented for DSM is load shifting. This has been proposed for the management of micro grids. However, there is lack of proper definition for DSM in relation to stand-alone grids focusing on the optimization of power generation management (Deindl et al., 2008). To apply DSM strategies effectively, a load control network must be built.

2.5 Energy efficiency practices in Ghana

The Ghana Shared Growth and Development Agenda (2010–2013) confirms the status of a secure and reliable supply of high quality energy services in all sectors of the economy as a prerequisite for Ghana’s development. This notwithstanding, Ghana suffers from a recurrent power crisis, which has led to the loss of a significant amount of output in the country. According to Braimah and Amponsah (2012), this loss in output is a build-up of time lost in production and joblessness created as a result of lack of alternative sources of power to bridge the gap between supply and demand. The Institute of Statistical, Social and Economic Research (ISSER, 2013) estimates that the contributions from the electricity sub-sector to GDP in 2011 and 2012 were at the level of 0.5% and its share in total industrial GDP in 2012 declined in total to 1.8%.

According to Gyamfi (2007) and Adom et al. (2012), the electricity problem in Ghana could easily be solved if attention were paid to the demand side of electricity in the country, as is done in this study. Adom et al. (2012) and Adom and Bekoe (2012) are the only authors whose study tried to estimate the demand dynamics for electricity in Ghana. However the authors’ inability to measure the impact of certain significant factors of demand and the price of electricity weakened their analysis.

The following short-term DSM strategies have been proposed by the government to increase energy efficiency in the country (Ofosu-Ahenkora, 2008):

1. The intensification of energy efficiency education.
2. The implementation of mandatory efficiency standards for room air conditioners and CFLs.
3. The supply and injection of 6 million CFLs by the government, expected to reduce peak demand by 200–240 MW – the cost of this option is US$60/MW capacity compared to US$1,000/MW for simple cycle gas turbines (SCGTs).

3. Methodology

This study applies the PGD, similar to the work of Ziolkowska and Ziolkowski (2015), but departs from existing literature by applying a dynamic dematerialization model to study energy efficiency in Ghana. Unlike Ziolkowska and Ziolkowski (2015), who focused on the transport sector, this study focuses on the efficiency of the aggregate use of different kinds of energy (fossil fuel, electricity and total energy consumption). The study goes further to identify energy efficiency practices of small- and medium-scale enterprises in rural Ghana and ascertain the barriers to energy efficiency. To achieve the second objective, 15 industries were selected from 4 regions: Central, Eastern, Greater Accra and Volta. The choice of the industry and regions was dictated by energy consumption rate, energy access rate and the selection of electric utility provider. Based on the classification of the Regional Project on Enterprise Development, the study categorizes small enterprises as those with 5–29 employees and medium-sized enterprises as those with 30–99 employees (Regional Enterprise Development, 2008).

Following the work of Ziolkowska and Ziolkowski (2015), a PGD which involves changes in population and changes in electricity and gasoline consumption is used. The data span the period from 1971 to 2013. The PGD is measured as follows:

$$PGDE_t = \Delta POP_t - \Delta EC_t \tag{1}$$

where $PGDE_t$ is the product generational dematerialization of electricity consumption at time t and POP_t is the population of Ghana at time t. From this, we derive the following equation for the efficiency of gasoline consumption:

$$PGDG_t = \Delta POP_t - \Delta GC_t \tag{2}$$

where ΔGC_t represents the dynamic changes in gasoline consumption in Ghana. Other variables (product generational dematerialization and population) are as defined in Equation (1). Equations (1) and (2) can be re-written as:

$$PGDE_t = (\frac{POP_t}{POP_{t-1}})*100\% - (\frac{EC_t}{EC_{t-1}})*100\% \tag{3}$$

$$PGDG_t = (\frac{POP_t}{POP_{t-1}})*100\% - (\frac{GC_t}{GC_{t-1}})*100\% \tag{4}$$

A positive PGD would mean that energy consumption decreased in the years analysed compared to the preceding years given what was expected to happen if all the population consumed energy in the same way. Conversely, a negative PGD would mean that the energy consumption increased given what was expected to happen if all the population consumed energy in the same way. Both outcomes would deliver policy-relevant information for decision making.

3.1 Description of data

Data for the study were collected from two sources. First, data for the PGD analysis were collected from the World Development Indicators (WDI) of the World Bank. Data on fossil fuel and energy consumption in kilotons of oil equivalent (ktoe) for the period 1971 to 2012 and on electricity in kilowatts per hour (kWh) and population figures from 1971 to 2012 were obtained from the WDI.

The second part of the study made use of data collected from SMEs in rural Ghana through a questionnaire and observation. The essence of using observation is to minimize the impact of social desirability biases, i.e. when respondents report things that may not be the fact on the ground or reflect actual behaviour (Brace, 2004). The sample size for the study is 160 SMEs in rural area as defined by the Ghana Population Census. The coastal zone of Ghana, which comprises the Western, Central, Greater Accra, Volta and Eastern Regions, is generally humid and is home to most energy-intensive SMEs. Four regions were selected: Central, Eastern, Greater Accra and Volta. The questionnaire was pre-tested to ascertain whether the respondents understood the questions asked and whether they were consistent with the objectives set out by the study. Numbers were assigned to the qualitative variables for the purpose of understanding the relationships between the variables. Parametric (Bonferroni) and non-parametric tests (Mann–Whitney and chi-squared tests) were used to test for non-response bias between the respondents and the non-respondents. These primary data were compared to data from the Ghana Statistical Service.

4. Analysis and Discussion

4.1 Product generational dematerialization (PGD)

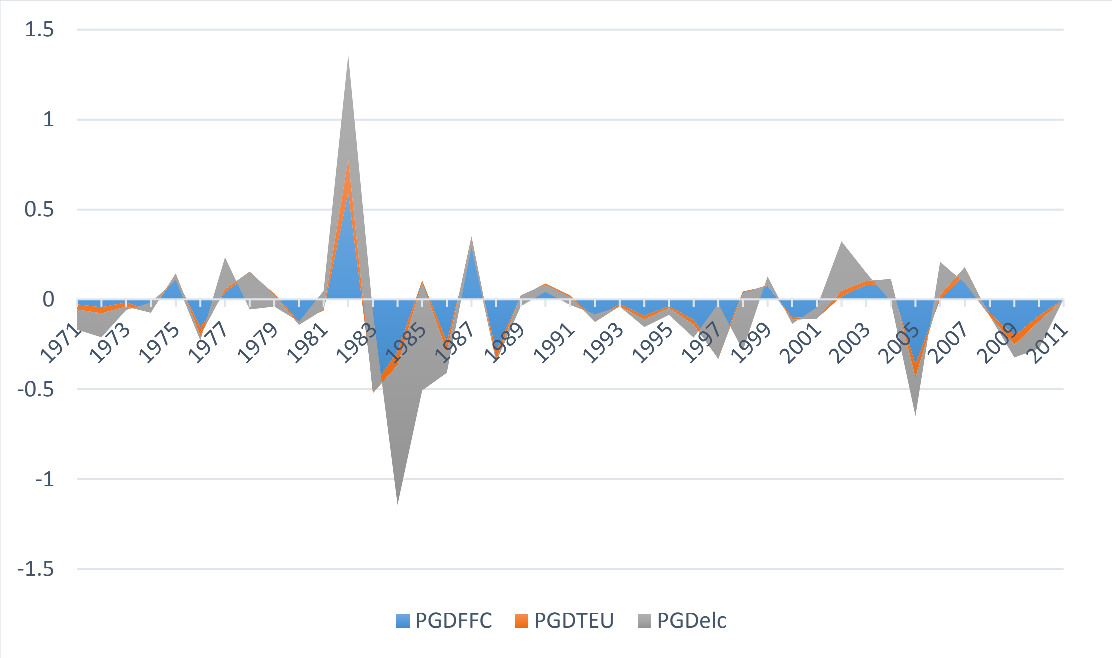

Figure 2. Results of product generational dematerialization

Figure 2 shows the PGD of fossil fuel consumption (PGDFFC), total energy consumption (PGDTEU) and electricity consumption (PGDelc) in Ghana from 1971 to 2011. The trends for all three variables show structural breaks and follow a similar pattern. Fossil fuel consumption showed a positive trend of generational dematerialization in 1975, 1981 to 1983, 1988, 1990, 2000, 2003 to 2004 and 2007. These changes in the trend could have been influenced by certain economic and political events that have impact on energy consumption. For instance, Ghana experienced a major drought from 1981 to 1985 which affected the water level of the Akosombo Dam, the main producer of electricity then. In addition, 1981 was associated with the end of the ascension to power of Flight Lieutenant Jerry John Rawlings of the Provisional National Defense Council (PNDC) and changes resulted in the suspension of the Constitution of Ghana and the banning of political parties. The economy suffered a severe decline soon after and the implementation of the World Bank sponsored structural adjustment plan and economic recovery programs changing many old economic policies. The structural adjustment programme witnessed a shift from agrarian based economy to gradual movement to industry based economy through divestiture of poorly managed public owned companies and, public-private investments. These structural changes had energy consumption implications. However, the general pattern suggests inefficiency in fossil fuel consumption. Finally, the PGD of total energy consumption is -0.27%. This implies that there is high efficiency in non-fossil fuel energy consumption such as renewables. As energy efficiency improvements rely on technological progress and behavioural changes, there should be systematic investments in energy efficiency measures and education to save money, save energy and also curb carbon emissions.

Overall, fossil fuel consumption recorded a PGD of -1.51% over the estimated period. This finding is in line with the PGD of Estonia (-1.5%) and Sweden (-1.4%) for non-renewable energy consumption reported by Ziolkowska and Ziolkowski (2015). The negative PGD for fossil fuel implies that energy consumption is growing faster than population growth. With carbon emissions from liquid fuel consumption increasing, there is a need for policy initiatives that will encourage efficiency in fossil fuel consumption.

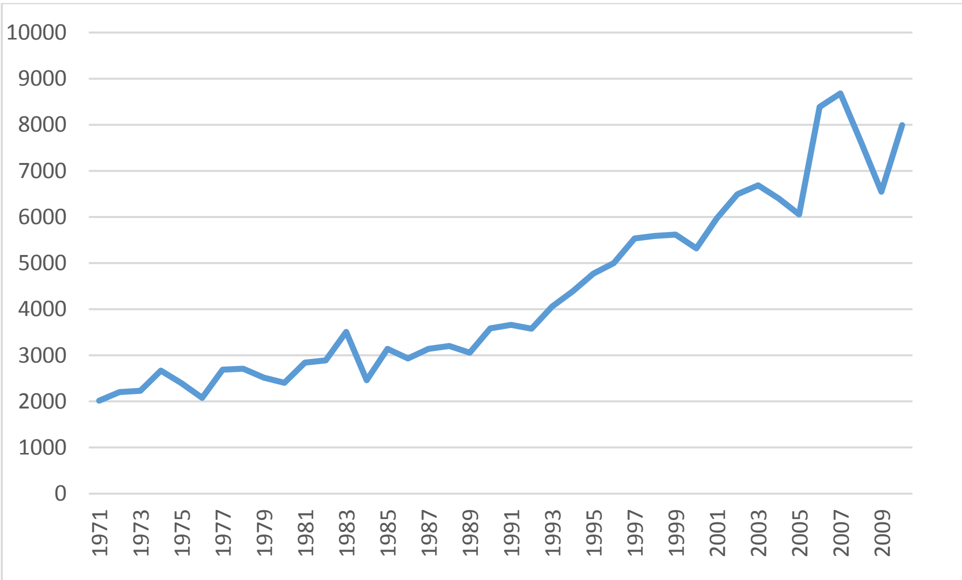

Figure 3. Carbon emissions of fossil fuel consumption

Figure 3 shows carbon emissions from liquid fuel consumption of 2016.85 kt in 1971. As at 2010, this had jumped to 7990.39 kt. Therefore, there is a need to implement measures that will promote investment in technology, reduce the imports of used vehicles and introduce efficient mass transportation systems to reduce the number of cars on the road, as well as educational promotion to target behavioural changes.

In 1997, the Ghana Energy Commission was launched as an agency to promote standards and efficiency in the use of energy. However, it has focused predominantly on the efficiency of electricity consumption at the expense of other fuel sources such as gasoline. For instance, the Ghana Energy Commission has introduced the ‘old fridge for new’ campaign to minimize waste in electricity consumption, coupled with educational campaigns that inform on the need to adopt efficient practices with regard to electricity. The PGD for electricity consumption was -1.11%, which is lower than that for fossil fuels. This means that more has to be done, especially in rural areas where some of these campaigns do not reach.

4.2 Energy efficiency of SMEs in rural Ghana

The study uses a survey conducted from November 2014 to March, 2015 in 4 out of the 10 regions of Ghana through a questionnaire. The essence of the study is to identify energy efficiency practices of SMEs in rural Ghana and ascertain whether these practices influence productivity. The reason for the rural emphasis is that few works that have been conducted on energy efficiency are concentrated in the urban areas (see Gboney, 2009). In addition, energy efficiency education is usually carried on televisions which may not be accessible by the rural population. Finally, since the Ghana Energy Commission is not decentralised, the old fridge for new one policy is centred in cities. In all, 200 questionnaires were distributed but only 160 were completed. The questionnaires were semi-structured with both closed and open-ended questionnaires. The high rate of response may be attributed to the high interest of the public in energy matters at the time of the study as a result of the Ghana power crises. Please see appendix 1 for a sample of the questionnaire. The industry were selected based on their connection to the electricity grid, operates within the rural Ghana and their preparedness to answer the questionnaires. The rationale of the using rural SMEs is that the work of the Energy Commission is mainly concentrated in the cities. The industry distribution is summarized in Figure 4.

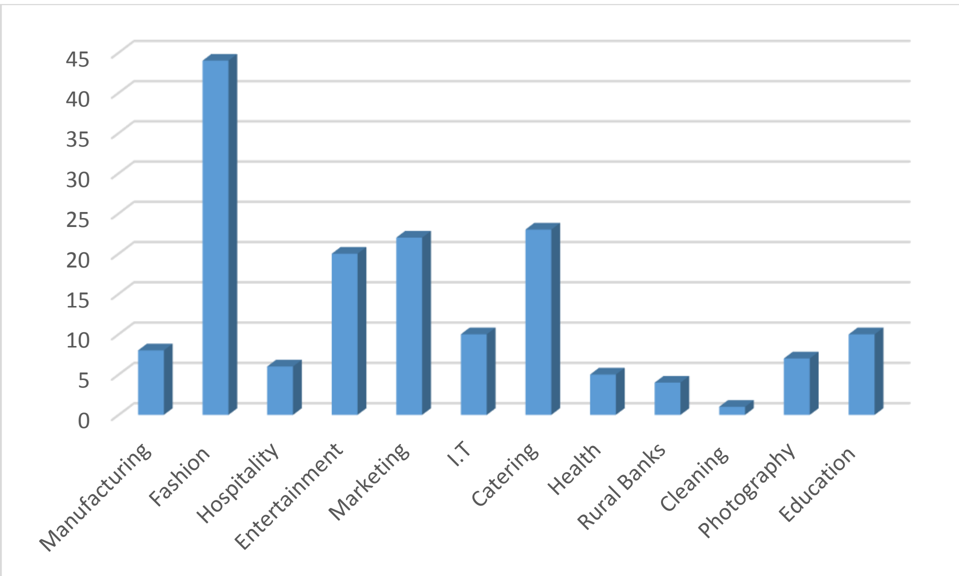

Figure 4. Industry distribution for data collection

Figure 4 highlights the industry categorisation of the respondents. Because hair dressing saloons, barbering shops and dress making shops are predominant in rural areas, the fashion industry provided the highest number of respondents, followed by the catering industry.

The results indicate that approximately 60% of the SMEs studied recorded a reduction in their electricity consumption over the preceding six months. However, 72% of these attributed the reduction in electricity consumption to blackouts (unreliable power supply).

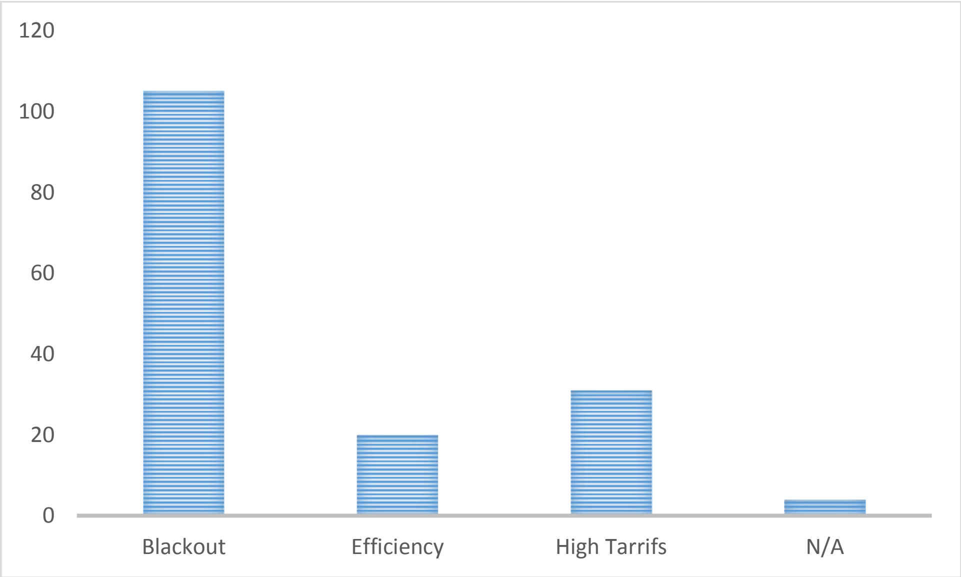

Figure 5. Causes of reduction in electricity consumption

According to Figure 5, the principal cause of the reduction in electricity consumption over the six months preceding the survey was blackouts according to 72% of those sampled. The study further finds that second most important driver of reduction in electricity consumption was increases in prices (5.7%). This confirms the findings of Adom et al. (2012), who find that price is a major driver of electricity consumption in Ghana. Finally, only 4.9% indicated that their reduced consumption resulted from energy efficiency. This finding has two important policy implications. First, policy makers can use price as a tool to achieve energy efficiency and climate change measures. Since consumers will have to pay more for a given unit of energy consumed, higher energy tariffs can serve as an incentive for consumers to make improvements in energy efficiency and lower their electricity use by investing in more efficient lighting and heating appliances or by installing higher quality insulation or windows. Second, the Ghana

Energy Commission, the main body charged with enhancing energy efficiency should adopt more pro-rural mechanisms and media to target and educate rural SMEs.

In Figure 6, the reasons for energy efficiency are identified. This is important for policy makers to use appropriate mechanisms such as price, mass communication and subsidies to encourage energy efficiency behaviour.

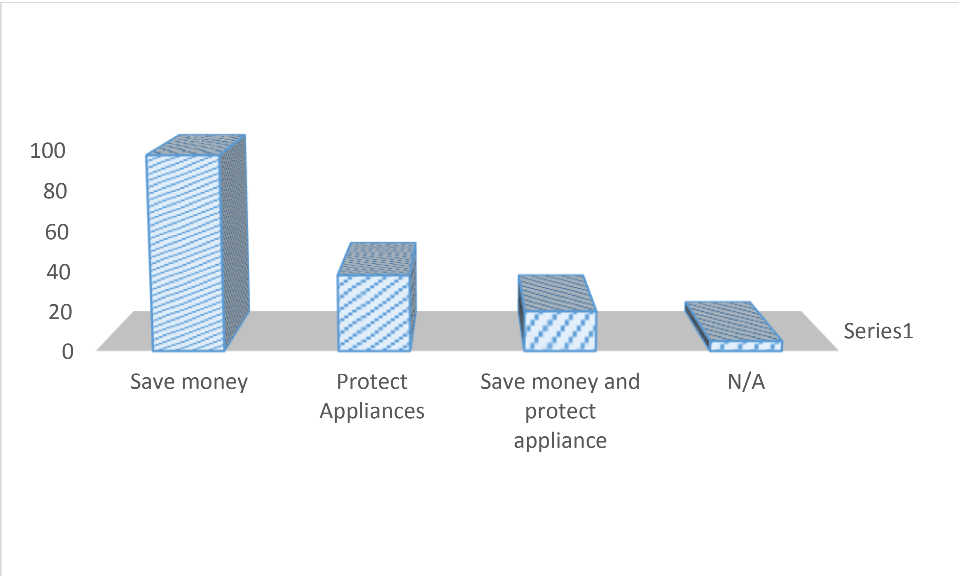

Figure 6. Reasons for energy efficiency behavior

In terms of where the respondents first heard about energy efficiency, 53% indicated radio and television, whilst 36.8% reported using their instincts in deciding whether they should adopt energy efficiency or not. Despite the effort of successive governments to encourage Ghanaians to use energy-saving bulbs by distributing 5,000 bulbs in 2007, approximately 54% of the respondents use the incandescent (‘onion’) bulbs, which have been found to be inefficient. The IEA estimates that CFL (energy saving bulbs) uses less than one-third to one-fifth the energy of incandescent bulbs. It is recommended that subsequent distribution of the energy-saving bulbs should consider SMEs in rural areas.

4.2.1 Other findings from SMEs survey

According to the findings, 60.5% turn off their appliances when not in use, 11% use fewer appliances to consume less and 8.3% of the respondents avoid the use of old or second-hand electrical appliances. Moreover, the three most important barriers to energy efficiency are lack of information on energy efficiency measures, lack of staff awareness and lack of technical skills. These barriers fall under the institutional and organizational barriers highlighted by Weber (1997). These findings mean that the Energy Commission needs to look at its communication strategy and devise means of training SMEs in energy efficiency measures. Whilst commendable efforts are being made by the Ghana Energy Commission and Ghana Energy Foundation to promote energy efficiency, most of these efforts seem to be concentrated in urban areas. In addition, the media used by the Energy Commission, such as TV3 and Metro TV, do not have nationwide coverage, depriving rural SMEs of opportunities to learn of energy efficiency measures.

Respondents were asked for their views on how to improve energy efficiency. For instance, 26.4% of the respondents called for public education on energy use and management, whilst 8.4% called on the government to resolve the power crises. Whilst public education on energy efficiency through mass media is ongoing, efforts should be made to include rural areas. In addition, the provision under the Renewable Energy Act (2011) that calls for subsidized solar panels should be operationalized to allow rural SMEs to minimize the impact of the power crises through sales and energy efficiency efforts.

4.3 Relationship between energy efficiency and productivity (Autometrics™)

Hendry and Krolzig (2005) suggest that model selection is a vital step in empirical research, especially when there are extant arguments over the choice of variables that affect a given phenomenon. As different sets of factors can potentially influence productivity, it is important to have an econometric approach that automatically selects the significant factors based on some predefined criteria. In Africa for instance, Bhattacharya and Timilsina (2009) suggests that due to factors such the transition from traditional sources of energy to modern commercial sources and the economic structure, productivity functions may be the same as those specified for developed countries. Automatic variable selection works by first specifying a general model based on previous findings, geographic and demographic characteristics and technological and economic trends. A misspecification test, lagged forms, significance levels and the desired information criteria are then established. This allows valid inference from the specification (Hendry and Krolzig, 2005). This step is followed by the elimination of insignificant variables.

To ascertain the relationship between energy efficiency and productivity, a general unrestricted model (GUM) consisting of all predictors is specified. *Autometrics*™ then uses a tree search to remove insignificant variables and select the final model (Pellini, 2014). According to Patterson (1996), energy efficiency (EE) can broadly be defined as the ratio of output (Y) over energy input (E) as follows:

$$EE = \frac{Y}{E} \tag{5}$$

More specifically, energy efficiency at the aggregate level can be obtained by dividing output by energy consumption (Ang, 2006). Therefore the more goods and services a country produces with a given amount of energy, the higher its energy efficiency. With regard to productivity, this study uses total factor productivity (TFP) as a proxy. This is because Zaman et al. (2011) highlight that the strong relationship between energy productivity and capital use indicates that energy efficiency may be augmented by optimizing capital use. Data on observed TFP for the period 1971 to 2010 were collected from the UNIDO global productivity database. TFP is calculated using *growth accounting* and is obtained by attributing the excess of the sum of labour and capital contribution to economic growth to productivity. For instance, using *Hicksian growth accounting,* we assume that a change in income (y) is the result of changes in capital (k), labour (l), productivity (a) and other factors (x), such as health, energy and quality of inputs. Thus:

$$\Delta y = \Delta a + \alpha \Delta k + \beta \Delta l + \rho \Delta x \tag{6}$$

Therefore, productivity becomes:

$$\Delta a = \Delta y - \alpha \Delta k - \beta \Delta l - \rho \Delta x \tag{7}$$

where A is a Hicksian demand function.

According to Boyd and Pang (2000), energy efficiency improvements have positive effect on worker productivity and the general productivity of companies through cost saving. In this paper, the Hicksian demand function is applied since it captures the effects of re-allocation of resources by examining the intuitive appeal of the Pareto improvements through the Kaldor-Hicks efficiency (Alston and Larson, 1993). ‘A’ is a Hicksian productivity indicator. We begin by specifying a GUM error correction model saturated with impulse indicators and step dummies with ‘A’ as the dependent variable:

$$\beta_{EE}(L)EE_t = \beta_0 + \beta_1 t + \beta_Y(L)Y_t + \beta_A(L)A_t + \beta_{EC}(L)EC_t + \beta_{CO2}(L)CO2_t + \sum_{j=1}^{J}(\beta_j I_{j,t} + \delta_j S_{j,t}) + u_t \quad (8)$$

Where i indexes country, t indexes time, $I_{j,t}$ is the impulse indicator dummy and $S_{j,t}$ is a step dummy. For all dummies, j is the indicator index. For instance, $I_{2004,t}$ means the impulse indicator dummy variable for 2004 that takes on the value 1 for 2004 onwards and 0 prior to 2004. $\beta(L)$ denotes a lag polynomial. Energy consumption (EC) is included in Equation (8) since it has been found that reduction in energy consumption improves productivity (Kander, 2002). Moreover, since one of the goals of productivity is to reduce carbon emissions (CO2), this paper examines how carbon emissions influence productivity (reverse causality). It is expected an inverse relation between carbon emissions and productivity.

To enhance the robustness of the model, a battery of misspecification tests are used for its evaluation. These tests include the autocorrelation test (Breusch and Godfrey, 1981) where the null hypothesis stipulates no serial correlation in the residuals. Moreover, the ARCH test (Engle, 1982) where the null stipulates no serial correlation in the squared residuals is employed. Other tests include the normality test (Bera and Jarque, 1982), which tests the normality assumption in residuals, the heteroskedasticity test of Breusch and Pagan (1979) that tests the assumption of constant error variance, and finally, the Reset test (Ramsey, 1974), which tests for linearity in the functional form of the regression.

The output of the GUM shows that there is a significant relationship between energy efficiency, energy-related carbon emissions and productivity (see Table 1).

Table 1. Estimation results on relationship between energy efficiency and CO_2

Predictors	Coefficient	Std. Error
1982 (Outlier)	-0.07	0.041
A	0.41	0.065
A(-4)	0.31	0.015
Diagnostics		
Std. Error		0.0011340
Normality test		1.5842
Normality test Chi 2(2)		2.135
Hetero test F(6,30)		0.551
Observations		37
DW		1.55
R^2		0.84

The results reveals that productivity is a major driver of energy efficiency in Ghana. Specifically, Table 1 suggests that a 1% increase in productivity increases energy efficiency by 0.41%. This confirms the findings of earlier studies (see Boyd and Pang 2000, Worrell et al,. 2003). This finding implies that as labour and capital spend less time and effort to achieve the same output, energy consumption reduces. Ghana experienced its first power crises in 1981/82. It is not surprising that the results indicate an inverse relationship between the outlier in 1982 and energy efficiency. Usually, power crises lead to excessive power consumption from inefficiency behaviour. For instance, if the lights go off on Friday, workers may not turn off the switch before leaving to the house. Therefore, if the light should be on by Saturday morning, there will be no one to put air conditions, bulbs and other appliances off until morning.

Figure 7 depicts variation over time in the energy intensity of Ghana. Ghana's energy intensity decreased from 1971 to 1983; it increased between 1983 and 1985, then remaining constant until 2001. The increasing trend after 2001 can be attributed to inefficiency in energy consumption, the increased share of heavy industrial manufacturing companies, structural changes and obsolete technology (Ma and Stern, 2008).

Even though Ghana is gradually moving towards a service-based economy, the consumption of energy is increasing. This may be driven by urbanization, economic growth and increased population.

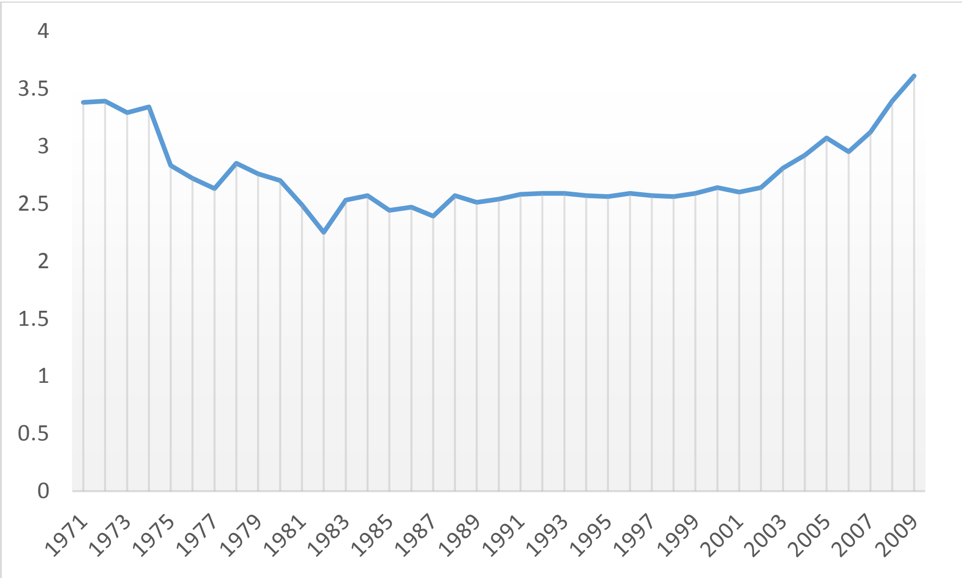

Figure 7. Ghana's energy intensity from 1971 to 2013

In terms of energy-related carbon emissions, the lagged values have a direct relationship with productivity. This implies that as consumers become aware of previous emissions as a result of energy use, they minimize their input use. Finally, the lagged dependent variable has a positive relationship with the current value of productivity.

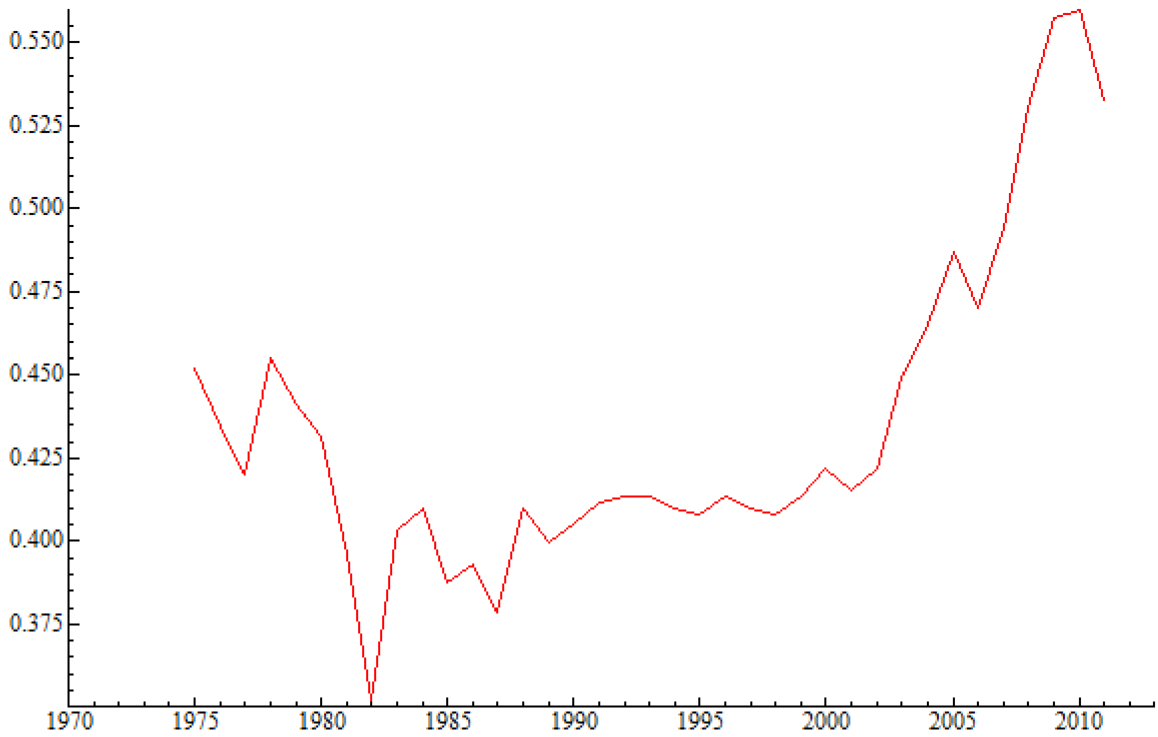

Figure 8. Underlying energy efficiency trend

Figure 8 shows the underlying energy efficiency trend of Ghana. This is adapted from Hunt et al. (2003), who measured the underlying energy demand trend. According to Dilaver and Hunt (2011), the slope of the line determines the extent to which behaviour is efficient. When the line slopes downwards, it shows generally efficient behaviour. According to Figure 8, Ghana was not particularly efficient until 1982, when the slope began to decline. This may be due to several factors. There was a downward trend in 2006 which can be attributed to the government distribution of six million energy saving incandescent bulbs in 2007 which saved 162.7 GWh annually. Post 2010 saw a sharp decline. Whilst this can be attribute to energy efficiency, it may also be due to the reduction of the manufacturing sector's contribution of GDP. The service sector, which consumes relatively less energy is now the number one contributor to GDP.

5. Conclusion and Recommendations

The purpose of this study was to identify the energy efficiency practices of SMEs in rural Ghana and also examine the barriers to implementing energy efficiency practices. Furthermore, the study sought to ascertain the relationship between energy intensity and productivity at both the aggregate and micro (SME) levels. To achieve these objectives, three methods were employed. First, a descriptive analysis was used to examine the barriers and energy efficiency indicators. Second, a two-stage least squares approach was applied to test the relationship between energy efficiency and productivity at the micro level. Finally, *Autometrics™* was used to examine the relationship between energy efficiency and productivity at the aggregate level.

The study finds that the energy consumption of most SMEs in rural Ghana has diminished. However, this reduction is attributed to the power crises and high electricity prices. Energy efficiency came third in the ranking of factors behind the reduction in electricity consumption. Furthermore, the study finds that most SMEs use post-paid meters despite efforts by policy makers to encourage the use of pre-paid meters as post-paid ones are inefficient and could be used as a tool to pay reduced bills. Moreover, 62% of the respondents indicated that energy efficiency leads to profitability through reduced electricity bills. The study also finds that lack of information on energy efficiency practices is the most important barrier to energy efficiency. In terms of the practices employed, methods such as turning off electrical appliances when not in use or when the business is closed, using new electrical appliances and using fewer appliances to achieve the same goal are some of the common approaches adopted by SMEs in rural Ghana. The results of the PGD reveal that the consumption of fossil fuel is relatively inefficient compared to electricity consumption. This may be due to the emphasis of the Ghana Energy Commission on electricity efficiency at the expense of other fuel sources.

The study recommends that the Ghana Energy Commission intensify its energy efficiency education and extend this to rural areas. In addition, associations and organizations such as churches and mosques can be used to train SMEs in rural areas on energy efficiency measures. Furthermore, the ‘old freezer for a new freezer’ programme should be extended to cover common appliances used by SMEs. As price is a vital factor in reducing energy consumption, policy makers should charge realistic prices for electricity to enhance efficiency. Moreover, policies should also target worker and capital productivity since this can reduce energy inefficiency. Finally, Ghana Energy should educate the public on the need to be efficient in terms of fossil fuel consumption to save energy, save money and curb carbon emissions.

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APPENDIX A.

QUESTIONNAIRE & INTERVIEW THEME QUESTIONS

University of Portsmouth, UK/United Nations University, INRA, Accra

Topic: Does efficiency lead to productivity growth? A study of energy efficiency practices and productivity growth in small and medium-sized enterprises in rural Ghana.

Dear Respondent,

This questionnaire is to collect primary data from respondents that will help to ascertain whether efficiency leads to productivity among rural SMEs in Ghana. It is part of my PhD thesis that is been facilitated by the United Nations University. It is in this respect that I am soliciting your cooperation to complete the questionnaire. The research is purely an academic work and information provided will be treated with utmost confidentiality. No part of the information will be made disclosed without prior consent from you.

I wish to express my sincere gratitude to you for taken time to participate in this research as a respondent.

Kind Regards.

QUESTIONNAIRE

PART A : COMPANY PROFILE

1. Identification

1. Name of Company……………………………………………………………………………………..
.....

2. Industry………………………………………………………………………………………

3. Company location (town and region)
…………………………………………………………………………………………...

4. Number of employee
…………………………………………………….................................

5. Monthly turnover (Approximation)………………………………………………………………………........

6. The company is owned by (a) male (b) female

PART B: ENERGY CONSUMPTION

7. Please indicate your company‘s approximate monthly expenditure on:

Petrol……………………………………………
Electricity…………………………………………

8. Do you use generator? (A) Yes (b) No

If no, kindly go to number 10

9. If yes, how many gallons do you buy in a day?

………………………………………………………………………………………

10. Do you check your energy consumption? (a) Yes (No)

If no, kindly go to 12

11. If yes, how frequent is your energy use generally recorded/checked? (a) Daily (b) Weekly (c) Monthly (d) Yearly

12. Are consumption records adjusted to energy price change? (a) Yes (b) No

13.Is a monitoring and targeting scheme employed? (a) Yes (b) No

14. Do you use post- paid metre or pre-paid (a) Post- paid (b) pre-paid

15. Why? (a) regulation (forced on you by law) (b) economic reasons (lower prices) (c) cannot access pre-paid metre (shortage on market)

(d) other, please specify……………….

16. Who connected your electricity for you?

(a) Myself (b) ECG staff (b) private electrician (d) other, please specify

PART C: ***ENERGY EFFICIENCY INDICATORS***

17. Over the past six months, has your energy changed? (a) Increased (b) decreased (c) the same

18. What accounted for the change?

(a) blackout (dumsor) (b) energy efficiency measures (c) increase in electricity prices (d) acquired new electrical gadgets (e) please specify……………………………………………………….

19. Do you have Automatic switch off of pumps, fans, conveyors & other Equipment when not required? (a) Yes (b) No

20. Do you Purchase of energy efficient computers, photocopiers & other Office equipment? (a) Yes (b) No

21. Are your electrical gadgets second hand or brand new (a) second hand (b) new (c) home use

22. Which type of electrical bulbs do you use ?

23. Where did you first hear about energy efficiency (a) TV and radio (b) Books (c) Instinct (d) other, please specify

24. Do you off your electrical gadgets when you close from work? (a) Yes (b) No

If no, explain

25. If yes why? (a) to save cost (b) protect it from damage in case of power outage (c) because others do it (d) other, please specify……………………………………….

26. What are the barriers to energy efficiency improvement in company?

(a) Lack of information on energy efficiency measures (b) lack of funds (c) I feel its not important (d) Lack of technical skills

(e) Lack of staff awareness

(f) other, please specify

26. What three things do you do to save energy?
1.
2.
3.

PART D: ENERGY EFFICIENCY AND PRODUCTIVITY GROWTH

27. How has been your profit over the past 6 months? (a) Increased (b) decreased (c) same

If decreased, why

If increased,

why……

28. Do you think energy savings enhance profit in your company? (a) Yes (b) No

If yes,

explain………………………………………………………………………………………

29. What energy efficiency measures are there in your company? (a) Training (b) Reward/punishment (c) other, please specify

30. Do you have any further comments on driving forces for energy efficiency improvement?
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Thank you.

Appendix B Tests